

Distribution, abundance and population structuring of beaked whales in the Great Bahama Canyon, northern Bahamas

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LONG-TERM GOALS

The long-term goal of this project is to fill key data gaps on the population ecology of beaked whales, specifically relating to distribution, habitat use, abundance and population structuring in the northern Bahamas.

OBJECTIVES

The objectives of the three-year study are:

- 1) To use visual survey techniques to document beaked whale distribution and habitat use, and to estimate abundance in the Great Bahama Canyon (Figure 1).
- 2) To use photo-identification techniques to extend an existing photographic catalogue of individual beaked whales, which will be queried to examine the distribution, movements and social affiliations of identified individuals, and to assess abundance using mark-recapture techniques.
- 3) To use remote biopsy techniques to collect skin and blubber samples to contribute to the study of beaked whale diet (through fatty acid, stable isotope and contaminant analyses) and stock structure (using molecular genetic approaches).
- 4) To develop and implement methods of detecting beaked whales using a towed acoustic array, compare visual and acoustic detection rates, and compare detection efficiency of the towed array and the bottom mounted hydrophones at the Atlantic Underwater Test and Evaluation Center.
- 5) To collect baseline data on the distribution, relative abundance and ecology of other cetacean species in this area, as well as data on sea turtles and bird species of note.

APPROACH

To accomplish our objectives, three one-month ship-based visual and acoustic surveys were conducted in the Great Bahama Canyon (Figure 1). These surveys occurred during different seasons, with two surveys in 2007 (May and October) and one survey in May 2008. Prior to the first survey, biopsy training took place off southwest Great Abaco Island, Bahamas, in a site where the Bahamas Marine Mammal Research Organisation (BMMRO) have been conducting studies on beaked whales since 1997 (for more information on BMMRO's study, see Claridge 2006). A further planned field component involves two additional one-month surveys with focused photo-identification and biopsy sampling of beaked whales in "hot spots" that have been determined from the existing survey data, as well as areas outside the Great Bahama Canyon (i.e. Exuma Sound and Great Abaco Canyon) to contribute towards an assessment of population structuring. The first of these surveys will take place in May 2009.

During the ship-based surveys, the survey design used standardized line-transect techniques to assess patterns of distribution and relative abundance. The Great Bahama Canyon was divided into four survey grids, with each grid running in the same orientation as a deep ocean channel (NE Providence Channel, NW Providence Channel, Tongue of the Ocean and the Cul de Sac) as shown in Figure 1. Transect lines were randomly placed within the four rectangular strata using a saw-tooth (zig-zag) pattern inside each grid to allow equal area coverage and ensure that the track lines randomly sampled the study area. Because these strata were slightly different sizes, the proportional area of each stratum was calculated and thus the length of track line needed in each to ensure equal area coverage. The angle of the saw-tooth track lines was then determined to meet this track line requirement.

For placing of track lines, a random start-point along the shortest side of each stratum was chosen, and a randomly chosen survey direction (up or down). The start point was chosen by dividing the width of each stratum into 1nm sections, and then using a uniform random number generator to select the increment at which to start in each stratum (in reference to the top left corner). The direction was chosen by using a U(0,1) random generator and choosing "up" if the number is >0.49 . New track-lines were drawn for each survey.

Protocols for data recording were based on previous line transect surveys (e.g. Zerbini *et. al* 2006) and were adapted to the survey as appropriate. A team of 7 – 9 scientists rotated through positions as observers, data recorder and acoustic monitor. Two primary observers were positioned on opposite sides of the observation platform (5 – 6 m height above sea level) and used fixed-mount Fujinon 25x magnification binoculars ("big eyes") to scan from 90° on their side and overlap 10° on the other side to provide greater coverage of the track line. A third observer was responsible for scanning the centerline (track line) and searching the near view with hand-held 7x magnification binoculars. Reticules in the binocular views were used to estimate distance to sightings, and the bearing ring on the bigeyes or fixed angle boards were used to record the bearing to the sighting relative to the path of the ship. The ship traveled at a speed of approximately 8 knots during the visual and acoustic surveys.

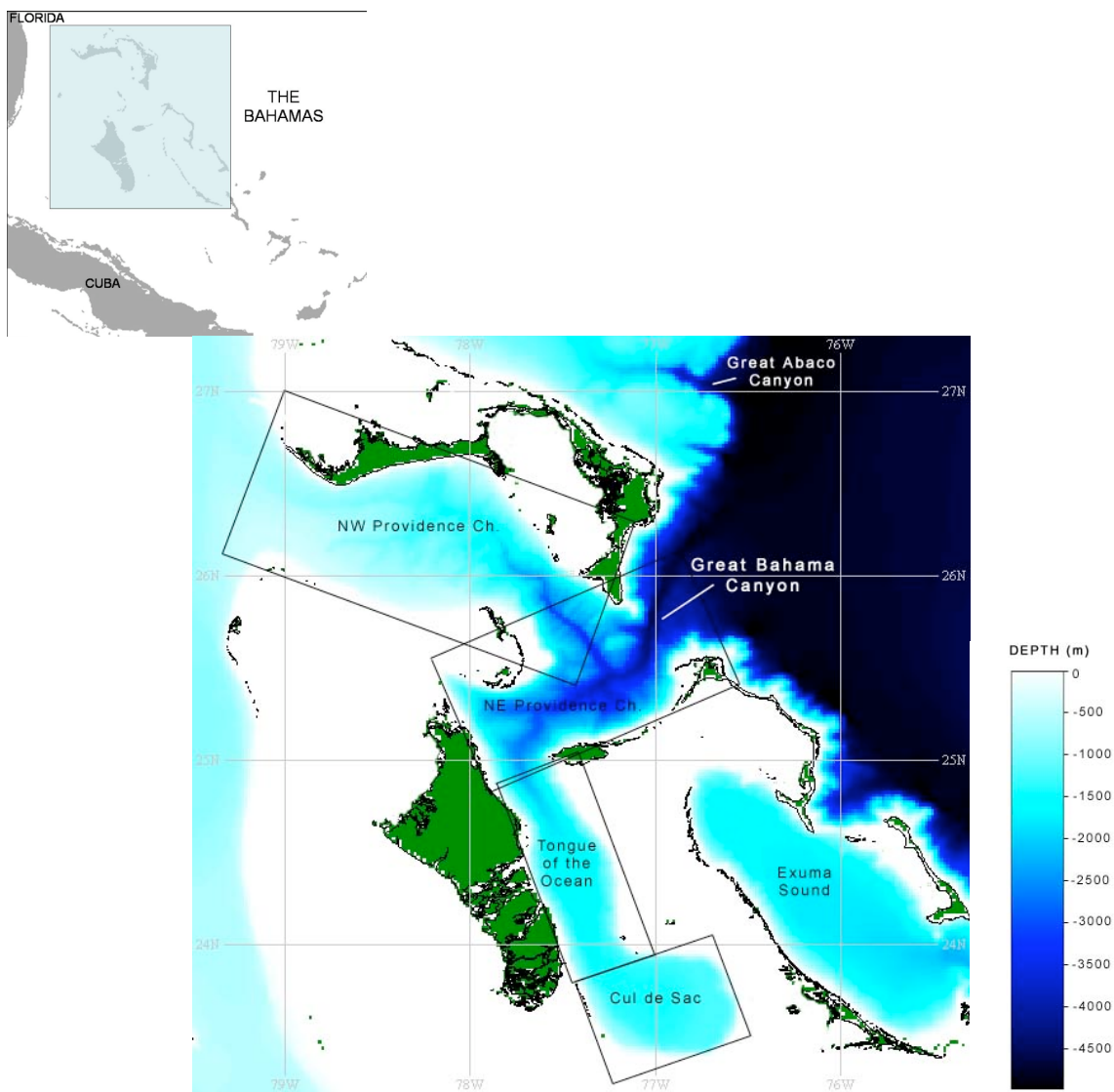


Figure 1. The Great Bahama Canyon branches into Northwest Providence Channel and from Northeast Providence Channel south into Tongue of the Ocean and the Cul de Sac. The canyon reaches depths of more than 4000m. The four survey grids are shown.

Upon sightings, the ship broke off the transect line for a close approach on the group when necessary to confirm species identification and to estimate group size. Closing mode was adopted for all sightings of beaked whales and sperm whales, and a 5.5 m or 6.8 m rigid-hulled inflatable boat (RHIB) was deployed for photo-ID and biopsy sampling. After each encounter, the ship returned to the transect line by converging back to the track line to avoid resightings of the same animals. Sightings which occur during passage back to the transect line were recorded as ‘off effort’.

Drs. Jonathan Gordon and Doug Gillespie (Sea Mammal Research Unit) constructed the towed hydrophone and Dr. Gordon joined the survey to oversee the acoustic survey. The hydrophone had 4 elements: two at 200 m and two at 400 m. Continuous recordings were made at a sampling rate of 192 kHz from the towed hydrophone arrays during line transect surveys as well as during times when

visual observers were off effort (e.g. at night). A beaked whale click detector and classifier was developed within Rainbow Click and PAMGUARD and this was both run in real time and used to analyze recordings to pick out beaked whale click trains. Some of this effort was done in conjunction with Dr. Dave Moretti (Naval Undersea Warfare Center) and his team monitoring bottom-mounted hydrophones at the AUTECH Tongue of the Ocean navy range to compare detections of beaked whales. [This report will not include results from the acoustic portion of the survey.]

WORK COMPLETED

The project has completed four different field efforts to date. A summary of the effort is provided in Table 1.

Table 1. Summary of the field effort undertaken to date during the Bahamas Beaked Whale Ecology Study. The number of beaked whale sightings and biopsy samples on each survey is shown with the total number of sightings and biopsy samples of all species given in parentheses.

Survey	Dates	Distance Surveyed (km)	Transect Lines Run	No. of Sightings	No. of Biopsy Samples
Biopsy Training (13 days)	October 2006 – May 2007	628	n/a	6 (21)	1 (1)
R/V <i>Odyssey</i>	5 May – 9 June 2007	1,791	19	9 (37)	1 (1)
M/V <i>Dolphin Dream</i>	28 Sept – 28 Oct 2007	2,855	29	21 (55)	3 (8)
R/V <i>Walton Smith</i>	15 May – 15 June 2008	3,611	37	47 (143)	33 (39)

The first two field efforts (the biopsy training and R/V *Odyssey* survey) were detailed in the previous report and are included here only to provide a summary of the work completed to date. Two additional visual and acoustic surveys of the Great Bahama Canyon have been completed: 31 days during September – October 2007 aboard the M/V *Dolphin Dream* (85 ft converted shrimp trawler) and 32 days during May – June 2008 aboard the R/V *Walton Smith* (95 ft power catamaran owned by the US Navy and operated by the University of Miami). The survey aboard the R/V *Walton Smith* was the most successful in running transect lines, finding beaked whales and most importantly closing on beaked whale groups to obtain individual identification photographs and biopsy samples, with an unprecedented number of samples obtained.

In all, the surveys have covered 8,885 km of visual search effort; including searches during 85 random transect lines. The track lines from each survey are shown in Figure 1, demonstrating the extensive coverage of the submarine canyon. During the *Walton Smith* survey, 6 transect lines were repeated, including 4 lines on the AUTECH Weapons Ranges as the first time these lines were run was the day following the end of the Submarines Commander Course. The lines were run again 2 days and 10 days later.

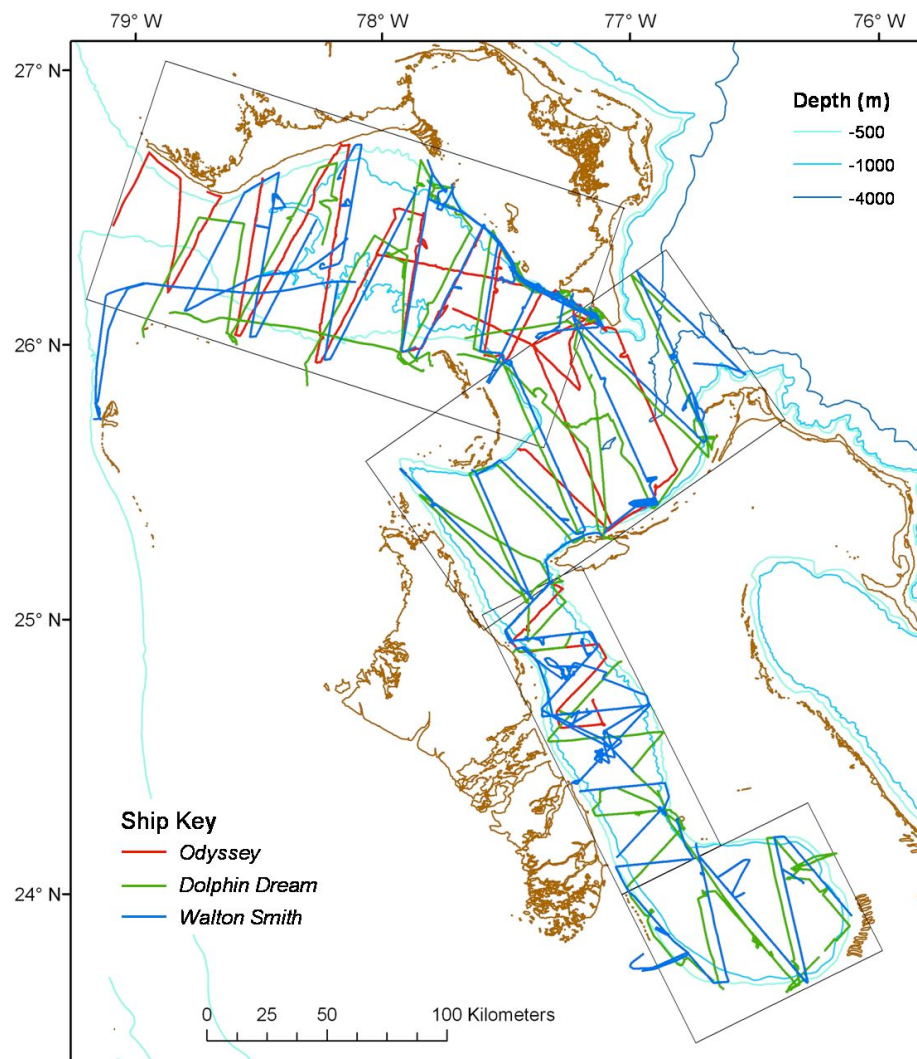


Figure 2. The ship track lines during the three month-long surveys when visual observers were on effort. Red lines represent track lines run during the “Odyssey” survey in May 2007 showing that almost all of the transect lines were completed in the NW Providence grid while only some or none were completed in the other three grids. Green lines represent track lines run during the “Dolphin Dream” survey in October 2007 and blue lines represent track lines run during the “Walton Smith” survey in May 2008 showing that almost all transects were completed during these two surveys.

The survey effort has resulted in 256 sightings of cetaceans, comprising 13 different species. Table 2 summarises the sightings data collected for each species. Members of the families *Kogiidae* (dwarf and pygmy sperm whales) and *Ziphiidae* (beaked whales) were the most frequently sighted with 88 and 83 sightings, respectively. Three beaked whale species were found: Blainville’s beaked whale (*Mesoplodon densirostris*), Gervais’ beaked whale (*Mesoplodon europaeus*) and Cuvier’s beaked whale (*Ziphius cavirostris*), with *M. densirostris* representing 55% of the Ziphiid sightings. Group sizes were similar for all three species, ranging from 1 – 5 whales (median = 3). A total of 218 beaked whales were sighted during the surveys. Biopsy attempts were made during close approaches to 34 groups of animals, resulting in the successful collection of 49 samples, of which 38 were beaked whale tissue samples. The skin and blubber cores were sub-sampled and stored in liquid nitrogen and/or preservative and shipped to the NOAA Southwest Fisheries Science Center (San Diego, CA) for

genetic analysis and NOAA Northwest Fisheries Science Center (Seattle, WA) for contaminant and diet analysis.

Table 2. List of the cetaceans sighted during the field effort to date (October 2006 – June 2008), showing the number of sightings for each species, median and range of group sizes and the total number of animals seen.

Species	No. of sightings	Group Size Median	Group Size Range	Total No. of Animals
Blainville's beaked whale (<i>Mesoplodon densirostris</i>)	46	3	1 – 5	134
Gervais' beaked whale (<i>Mesoplodon europaeus</i>)	3	3	2 – 4	9
Cuvier's beaked whale (<i>Ziphius cavirostris</i>)	21	3	1 – 4	51
Unknown Ziphiid species	13	1	1 – 5	24
Sperm whale (<i>Physeter macrocephalus</i>)	33	3	1 – 9	102
Dwarf sperm whale (<i>Kogia sima</i>)	57	1	1 – 8	117
Pygmy sperm whale (<i>Kogia breviceps</i>)	13	1	1 – 4	19
Unknown <i>Kogia</i> species	18	1	1 – 3	24
Short-finned pilot whale (<i>Globicephala macrorhynchus</i>)	1	12	n/a	12
Pygmy killer whale (<i>Feresa attenuata</i>)	1	10	n/a	10
Melon-headed whale (<i>Peponocephala electra</i>)	1	200	n/a	200
Rough-toothed dolphin (<i>Steno bredanensis</i>)	1	14	n/a	14
Pan-tropical spotted dolphin (<i>Stenella attenuata</i>)	9	15	4 – 100	197
Atlantic spotted dolphin (<i>Stenella frontalis</i>)	5	12	2 – 14	44
Atlantic bottlenose dolphin - oceanic ecotype (<i>Tursiops truncatus</i>)	3	2	1 – 50	53
Atlantic bottlenose dolphin - coastal ecotype (<i>Tursiops truncatus</i>)	11	3	1 – 10	34
Unknown cetacean	20	1	1 – 6	39

RESULTS

The survey design employed for the ship-based surveys has worked well to cover the deep-water habitats of the Great Bahama Canyon, and we have been able to identify “hot spots” showing preferred habitat for beaked whales. The spatial distribution of beaked whale sightings made during the surveys is shown in Figure 3. The majority of sightings were in the northwestern part of the canyon in NW Providence Channel and at the southernmost part of Tongue of the Ocean, in the Cul de Sac. It is notable that these are the two “ends” of the canyon, with respect to deep water channels. Similarly, although beaked whales were distributed throughout the canyon, the highest densities appear to be along the canyon wall. The cluster of sightings off the southwest coast of Abaco Island reflects opportunistic effort during each survey when the ship worked in the lee shore which provided increased opportunities for finding animals.

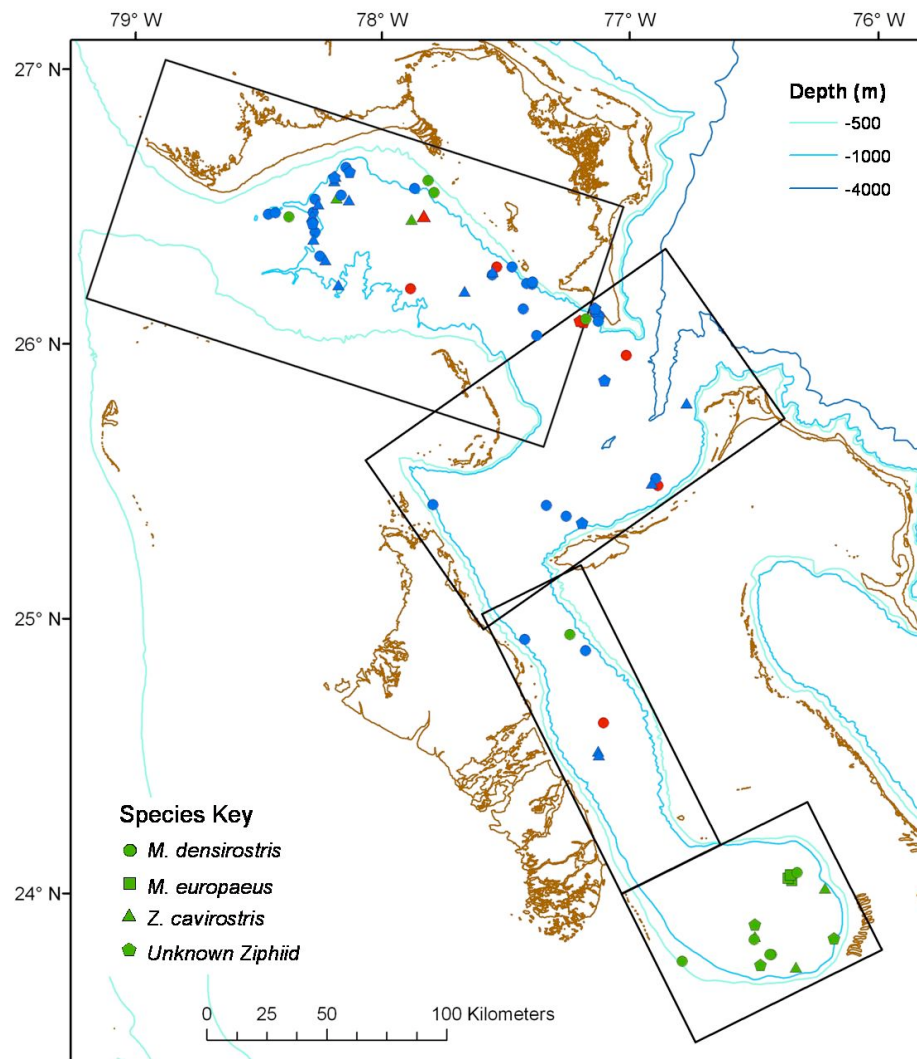


Figure 3. Map of the Great Bahama Canyon showing the locations of beaked whale sightings during the three month-long surveys. “Odyssey” sightings are shown in red, “Dolphin Dream” sightings in green and “Walton Smith” sightings in blue. Although beaked whales are found throughout the canyon, the distribution appears to be associated primarily with the canyon wall, with the highest densities found at the western end of the canyon in NW Providence Channel.

IMPACT/APPLICATIONS

Mass strandings of beaked whales in several areas (Simmonds and Lopez-Juraco 1991; Frantzis 1998; Jepson *et al.* 2003), including the northern Bahamas (Balcomb and Claridge 2001, Evans and England 2001) have correlated with international naval operations. The US Navy has two operating areas within the Great Bahama Canyon: the Atlantic Underwater Test and Evaluation Center and the Shallow Water range in the northern Berry Islands. This project has taken the first steps towards providing information on the baseline population ecology of beaked whales in these areas and adjacent waters to understand and mitigate the effects of naval activities.

The sighting data collected during the surveys has shown that the marine mammal fauna of the canyon is primarily represented by deep-diving pelagic species, including all three beaked whale species known from the Bahamas. The densities of all cetacean species appear to be low in the canyon (only 1083 animals sighted in 8,885 km of survey effort). Current mitigation by the US Navy primarily comprises visual searches for animals. This is probably not very effective during exercises in the Great Bahama Canyon because the species most represented (*Kogia* and Ziphiids) are difficult to detect visually as they spend very little time at the surface, exhibit cryptic behavior when at the surface, and are found in small groups. The use of passive acoustics during the Marine Mammal Monitoring on Navy Ranges (M3R) program currently in place at the AUTEC range greatly improves mitigation for some species, including beaked whales when they are foraging, but as yet does not provide any information on presence of *Kogia* during operations and does not help with mitigation outside the AUTEC Weapons Ranges.

The highest densities of beaked whales appear to be in the Northwest Providence Channel which may explain why the highest mortality of beaked whales during the March 15, 2000 anti-submarine warfare GAP exercise occurred along the southern coast of Grand Bahama Island. However, these results are preliminary and should be interpreted as such. Further detailed analyses of the survey data has begun to estimate abundance and densities of beaked whales in relation to habitat, including fixed physical variables, environmental variables and biomass (as a proxy for prey densities). Analysis of the photo-identification data will allow us to assess movement of individual whales throughout the canyon, determine rates of emigration and immigration (turnover) on the AUTEC ranges, and to understand the difference in spatial distribution of different age and gender classes. Another survey is planned for May 2009 to obtain more biopsy samples, with an emphasis on increasing the sample size from the Tongue of the Ocean, especially the Cul de Sac, and will contribute to the assessment of the population structuring of Ziphiid species. This multi-faceted approach to the project will result in a comprehensive understanding of the population ecology of beaked whales on and around the US Navy ranges in the Bahamas.

RELATED PROJECTS

Behavior Response Study (BRS)

This is a large, multi-national project in which responses of whales exposed to underwater sounds are measured to identify and mitigate their adverse effects. Phase I of the study took place in Tongue of the Ocean and was led by Dr. Ian Boyd (SMRU) as the Chief Scientist and holder of Bahamian research permit, and the Principal Investigator and holder of US permit was Dr. Brandon Southall (National Oceanographic and Atmospheric Administration (NOAA)). The project is supported by the Office of Naval Research (ONR) and US Department of Defense (NAVSEA PEO IWS Mr. Joseph

Johnson and OPNAV N45 Dr. Frank Stone). Diane Claridge is a co-Principal Investigator. Photo-identification data and tissue samples collected during BRS will be contributed towards analysis of population structuring of beaked whales in the Great Bahama Canyon.

Dolphins and Whales of Abaco Island

This project is a long-term field effort studying the distribution, occurrence and abundance of cetaceans off Great Abaco Island, in the northern Bahamas. The project has been funded by an annual grant from Earthwatch Institute since 1992 and is led by Charlotte Dunn and Diane Claridge (Bahamas Marine Mammal Research Organisation) as co-Principal Investigators. The weblink is: <http://www.earthwatch.org/expeditions/claridge.html>. Photo-identification data and tissue samples collected during this project will be contributed towards analysis of population structuring of beaked whales in the Great Bahama Canyon.

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